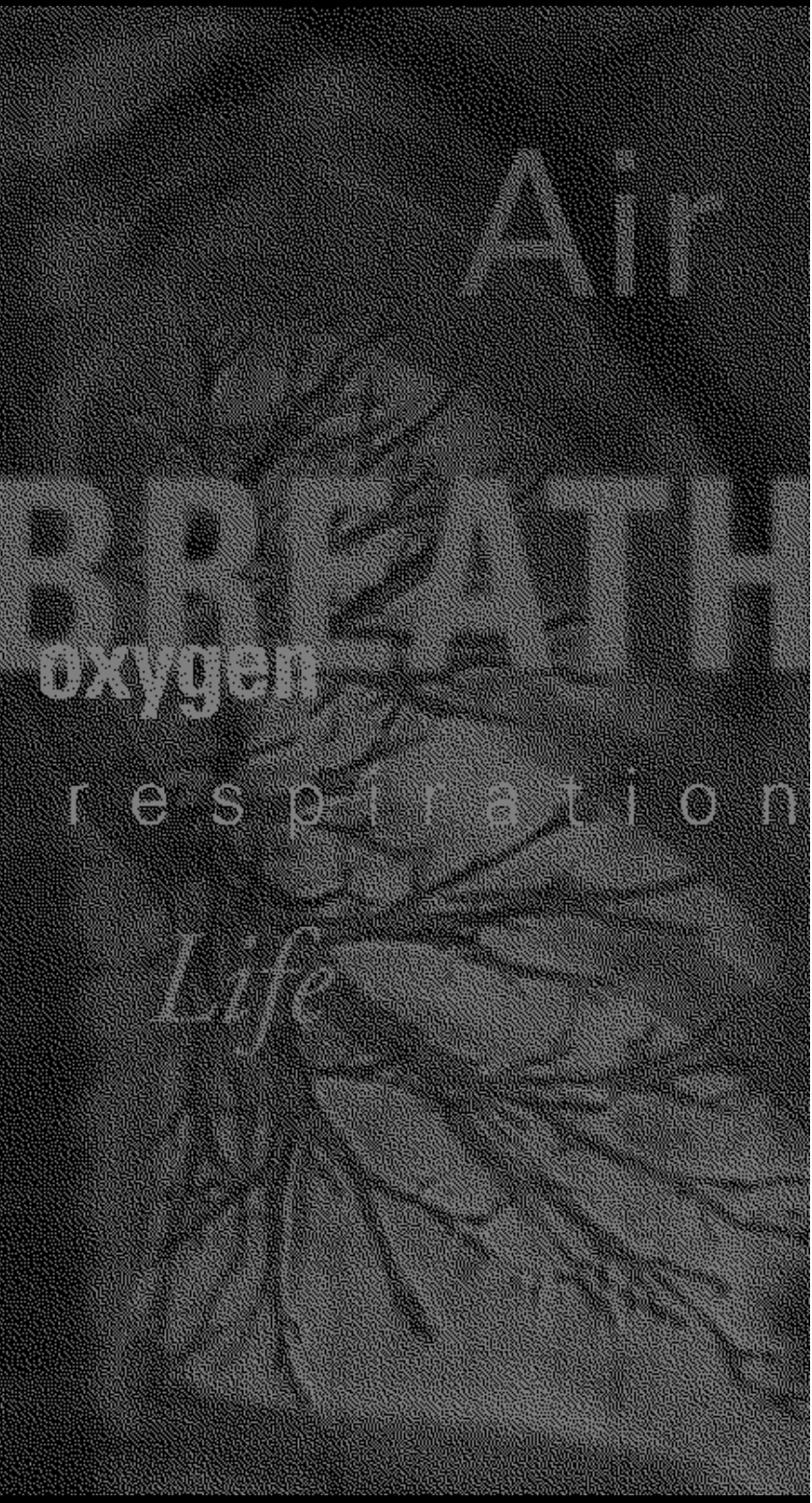
Division of Lung Diseases



THE LUNGS IN HEALTH AND DISEASE

NATIONAL INSTITUTES OF HEALTH
NATIONAL HEART, LUNG, AND BLOOD INSTITUTE

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Introduction

Breathing for most of us is something we do without being aware of it. We pay no attention to this continuous activity as we work, play, or sleep. Our lungs are responsible for this essential natural function that gets oxygen into the bloodstream so that it can be delivered to the cells of our body.

During a normal day, we breathe nearly 25,000 times. The more than 10,000 liters of air we inhale is mostly oxygen and nitrogen. In addition, there are small amounts of other gases, floating bacteria, and viruses. It also contains the products of tobacco smoke, automobile exhaust, and other pollutants from the atmosphere in varying amounts.

Air pollutants can affect our lungs in many ways. They may simply cause irritation and discomfort. But sometimes inhaled materials can cause illness or death. The lungs have a series of built-in mechanical and biological barriers that keep harmful materials from entering the body. In addition, specific defense mechanisms can inactivate some disease-causing materials.

However, sometimes the normal lung defenses and barriers in the lungs do not work as well as they should. Medical problems at birth or during infancy and growth can affect lung development. Later in life the lungs may be damaged by smoking, occupational exposures, or accidents. These abnormalities allow air pollutants to break through the lung's defenses. The result can be respiratory problems or diseases.

This brochure describes the unique structure and functions of the human lung that help maintain respiratory health. It explains how the lungs' inability to carry out their tasks can cause disease

or disability. It also lists some simple suggestions for warding off conditions that cause the lungs to malfunction. This booklet is offered by the National Heart, Lung, and Blood Institute (NHLBI) together with the National Lung Health Education Program (NLHEP) to meet the common goal of promoting lung health and preventing or reducing lung disease.

The Lungs: A Historical View

The lungs were once thought to be a solid mass.

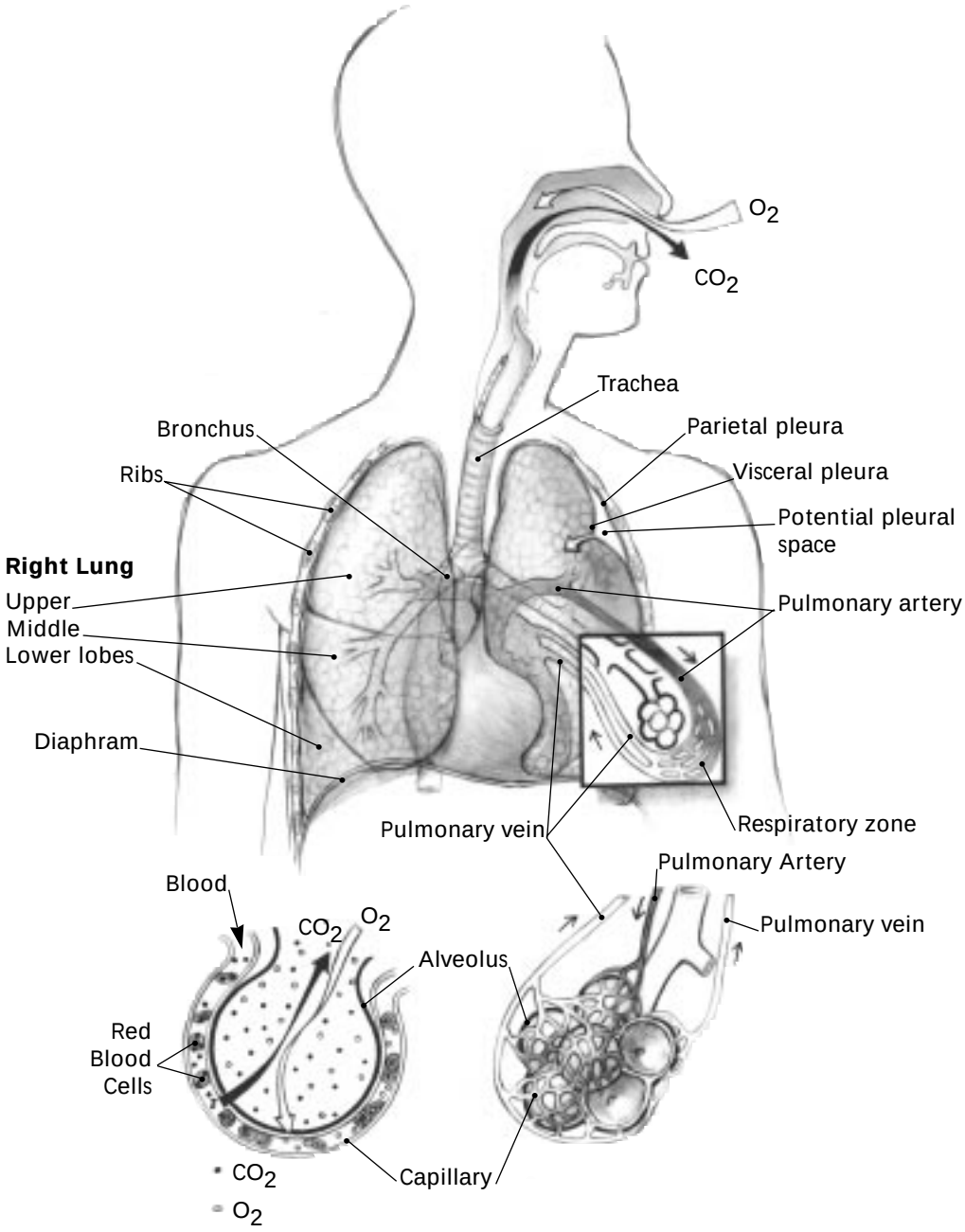
Nearly 2,000 years ago, Claudius Galen, a Greek physician, wrote that the lung was an instrument of voice and respiration. He thought that the purpose of respiration was to cool the heart by "the substance of the air." His concept was that breathing in (inspiration) supplied a cooling substance to the heart while breathing out (expiration) removed hot material from it. At the end of the 16th century, a Dutch scientist, Fabricius, expressed the view that the function of the lungs was to prepare air for the heart.

Until the middle of the 17th century, the lungs were thought to be a solid, compact, fleshy mass. At that time Marcello Malpighi, an Italian anatomist, and Thomas Willis, an English clinician, noted independently that the lungs were a system of canals made up of membranes, air passages, and blood vessels. Many of the currently used terms for the components of the lung such as lobules, alveoli, arteries, and veins come from these authors. In 1628, William Harvey, a British physician and physiologist, described his theory of circulation and proposed that the blood was pumped through the lungs by the expansion and contraction of the lungs during breathing.

Our knowledge about the lungs has come a long way during the more than 300 years since Malpighi, Willis, and Harvey. Today we know that the lungs are a pair of cone-shaped, soft, spongy, pinkish, organs. They get oxygen into the blood and remove carbon dioxide, a waste-product of the body. We have also learned that a major function of the lungs is to protect the body from potentially harmful airborne agents and toxic chemicals that our body may produce.

We now know that the lungs have both “respiratory” and “nonrespiratory” functions. The respiratory function of the lungs is “gas exchange.” This is the term for the transfer of oxygen from the air into the blood and the removal of carbon dioxide from the blood.

The nonrespiratory functions of the lungs are mechanical, biochemical, and physiological. The lungs provide the first line of defense against airborne irritants and bacterial, viral, and other infectious agents. They also remove volatile substances and particles of matter generated within the body. The lungs control the flow of water, ions, and large proteins across its various cellular structures. Together with the liver, they remove various products of the body’s metabolic reactions. The lungs also manufacture a variety of essential hormones and other chemicals that have precise biological roles.



Lung Structure and Respiration

Inhaled air travels through the airways to the alveoli. Blood is pumped out of the heart through the pulmonary arteries to a network of capillaries that surround the alveoli. The oxygen of the inhaled air diffuses out of the alveoli into the blood while carbon dioxide in the blood moves into the alveoli to be exhaled. The oxygen-rich blood is returned to the heart through the pulmonary veins.

Lung Structure And Function: The Big Picture

The lungs are shaped like cones and textured like a fine grained sponge that can be inflated with air. They sit within the thoracic cage where they stretch from the trachea (windpipe) to below the heart. About 10 percent of the lung is solid tissue, the remainder is filled with air and blood.

This unique structure of the lung is delicate enough for gas exchange and yet strong enough to maintain its shape and enable it to perform the many functions vital for keeping us healthy. Two "plumbing" systems, the airways for ventilation (exchange of air between the lungs and the atmosphere) and the circulatory system for perfusion (blood flow), are coordinated by special muscles and nerves. This arrangement enables the lung to perform its primary function of rapidly exchanging oxygen from inhaled air with the carbon dioxide from the blood.

Air enters the body through the nose or the mouth, and travels down the throat and trachea into the chest through a pair of air tubes called bronchi (plural for bronchus). The bronchi divide and subdivide into successive generations of narrower and shorter branching tubes of unequal length and diameter. The final destination for inhaled air is the network of about 3 million air sacs, called alveoli, located at the ends of the lungs' air passages. Between the trachea and alveoli, the lungs look like an inverted tree.

The first (main) branching of the trachea leads to the left and right lungs. The two lungs fill most of the chest cavity. Between the lungs are located the heart, the major blood vessels, the trachea, the esophagus (tube leading from the throat to the stomach), and lymph nodes. The thorax (chest wall) surrounds and supports the lungs.

Movement of the air into the lungs is controlled by the respiratory muscles of the thorax. These muscles, collectively called the ventilatory apparatus, include the diaphragm (the muscle that separates the chest and abdominal contents) and the muscles that move the ribs. When the respiratory muscles contract, the chest enlarges like a bellows sucking in air (inhalation). As air fills the lungs they expand automatically. The lungs return to their original (resting) size when we exhale. The performance of the ventilatory apparatus is coordinated by specific nerve sites, called respiratory centers, located in the brain and the neck. The respiratory centers respond to changes in oxygen, carbon dioxide, and acid levels in the blood. Normal concentrations of these chemicals in arterial blood are maintained by changing the breathing rate.

The right lung is slightly larger than the left lung and is divided into three sections or lobes; the left lung has only two lobes. Each lobe is subdivided into two to five bronchopulmonary segments. The segments are further subdivided into lobules served by smaller branches of the bronchi.

The outside of the lung and the inside of the chest cavity are lined by a single continuous membrane called the pleura. The portion of the pleura surrounding the lungs is called the visceral pleura, while the portion lining the chest cavity is called the parietal pleura. The potential space between the lungs and the inside of the chest cavity is called the pleural space or pleural cavity. The pleural space is moistened with a fluid that lubricates the pleurae as they slide back and forth on each other during ventilation. Normally the pleural space contains only a small amount of fluid and is free of any gas, blood, or other matter.

Blood vessels, bronchi, and nerves come together at the entrance of the lung called the hilum. Bronchopulmonary lymph nodes, important for the drainage of the lungs, are located here. The extensive nervous system of the lungs extends from the hilum to almost all of the lungs' structural units.

The Conducting Airways

The first 16 subdivisions of the bronchi ending in terminal bronchioles are called the conducting airways. Terminal bronchioles are the smallest airways without alveoli. They further divide into respiratory bronchioles, ending in alveolar ducts. Respiratory bronchioles have occassional alveoli budding from their walls, while alveolar ducts are completely lined with alveoli. The last seven branchings of the bronchioles where gas exchange occurs are called the respiratory zone. The terminal respiratory unit of the lung from the respiratory bronchiole to the alveolus is called the acinus.

Gas Exchange

Gas exchange between inhaled air and blood takes place in the alveoli. Blood is brought to the alveoli through a fine network of pulmonary capillaries where it is spread in a thin film. The barrier separating the air and blood is extremely thin, 50 times thinner than a sheet of tissue paper. A large surface area (80 square meters, as large as a tennis court) is available for gas exchange. In the resting state, it takes just about a minute for the total blood volume of the body (about 5 liters) to pass through the lungs. It takes a red cell a fraction of a second to pass through the capillary network. Gas exchange occurs almost instantaneously during this short period.

The Lung of the Unborn Baby (Fetus)

Most of the respiratory needs of the fetus are provided by the mother. The fetal lung is filled with amniotic fluid and has none of the gas exchange function that it will have after birth. It is thus different from the fetal heart, kidneys, and liver, all of which begin their lifelong functions early in fetal life and increase their capabilities as the baby grows in its mother's womb.

The main functions of the fetal lung are to produce amniotic fluid and a material called surfactant that reduces the surface tension of the fluids that line the bronchioles and alveoli. Surfactant is necessary to clear liquid from the fetal lungs so that they can fill with air when the baby begins to breathe immediately after birth. Along with the first breath, a variety of circulatory and respiratory changes begin. These changes are necessary for the baby to live outside its mother's womb.

Surfactant production must continue after birth, since it maintains the mechanical stability of alveoli and prevents their collapse. Lack or deficiency of surfactant in infants causes Respiratory distress syndrome (RDS), a disease in which it becomes harder and harder for the baby to breathe. Lack of surfactant is also a factor in adult lung disease.

Lung Diseases: How They Begin

Some lung disorders are caused by general diseases of muscles or nervous systems.

The most common clinical signs of lung diseases are cough, chest pain, chest tightness, shortness of breath (dyspnea), and abnormal breathing patterns. When any of these symptoms appear, it may signal that some vital functions of the lung have been disturbed. Because most individuals have enormous reserves of lung tissue, the disturbances in lung defenses or function may have begun some time before the clinical symptoms begin to appear.

Respiratory problems can have a number of causes. They usually arise from acute or chronic inhalation of toxic agents in the workplace or other settings, accidents, or harmful lifestyles such as smoking. Infections, genetic factors, or anything else that directly or indirectly affects lung development and function can also cause respiratory symptoms. In some lung diseases, the lung itself has been damaged. Others result from diseases of the nervous system or the muscles. These disorders interfere with the normal function of the respiratory muscles so that, although the lung itself is normal, breathing is difficult.

Facts About Some Lung Diseases

Estimates of the number of known lung diseases vary from a few dozen to several hundred. Lung diseases are classified and counted either as individual, specific diseases, or as groups of diseases that share common features. These features may be their sites, etiologies (initiating events), pathophysiology (abnormalities of function), or clinical features (signs and symptoms).

Normal Lung

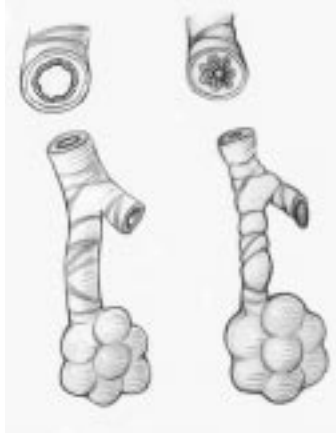
Most doctors find it convenient to deal with lung diseases in groups, based on the particular pulmonary (lung) component that is diseased. Examples are diseases of the airways, diseases of the interstitium (the space between tissues), or disorders of the pulmonary circulation, the ventilatory apparatus, or gas exchange. Often, many of these diseases occur together, particularly if they are caused by infection, inflammation, or cancer. In such cases they present an overlapping, progressive series of a mixture of clinical symptoms.

Diseases of the Airways

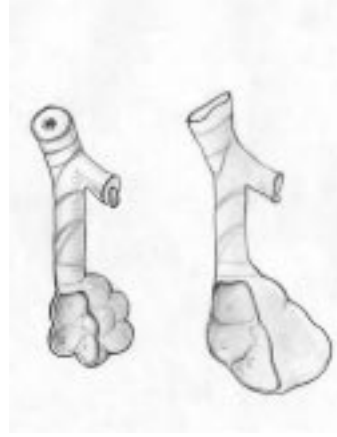
Airways diseases are lung disorders that are primarily due to a continuing obstruction of airflow. Acute or chronic airflow obstruction or limitation can be caused by a variety of structural changes in the airways. Asthma, chronic bronchitis, emphysema, bronchiolitis, cystic fibrosis, and bronchiectasis are some common airways diseases.

The term chronic obstructive pulmonary disease (COPD) is commonly used for chronic bronchitis and emphysema that exist together in many patients and in which the airway obstruction is mostly irreversible. COPD is the fourth most common and the most rapidly increasing cause of death in the United States.

■ In *asthma*, reversible airway obstruction is caused by inflammation, contraction of the airway smooth muscle, increased mucus secretion, and plugging of the bronchioles.



Normal Airway Asthma



Bronchitis Emphysema

- In *chronic bronchitis,* airway obstruction results from chronic and excessive secretion of abnormal airway mucus, inflammation, bronchospasm, and infections.

Emphysema

- In *emphysema,* a structural element (elastin) in the terminal bronchioles is destroyed leading to collapse of the airway walls and inability to exhale "stale" air.
- *Bronchiolitis* in children is due to viral infections that cause obstructive inflammatory changes in the bronchioles.
- In *bronchiolitis obliterans* (obliteration of bronchioles, occurring in transplanted lung or after bone marrow transplantation), inflammatory changes that occur in transplanted lungs eventually cause blocking of the lumen (air channel) of the bronchioles; this is a sign that the new lung is being rejected.

- *Cystic fibrosis* is a genetic disease in which thickened airway mucus, pulmonary infections, and inflammation lead to bronchiectasis and airway obstruction.
- In *bronchiectasis,* airway obstruction is due to chronic abnormal dilation (stretching) of the bronchi and the destruction of the elastic and muscular components of the bronchial walls; it is usually caused by repeated lung infections.

Bronchiectasis

Diseases of the Interstitium

The interstitium (the space between tissues) of the lungs includes portions of the connective tissue of the blood vessels and air sacs. Major chronic diseases of the lower respiratory tract in which fibrosis (scarring of the lung tissue) occurs affect the interstitial tissue. *Sarcoidosis* and *pulmonary fibrosis* are examples of the more than 150 interstitial lung diseases. Another term for these diseases is "stiff lung" disease. The most common symptoms are shortness of breath after exercise and a nonproductive cough. Some patients with interstitial lung diseases have fever, fatigue, muscle and joint pain, and abnormal chest sounds. As these diseases advance, heart function is affected.

Some interstitial lung diseases are caused by occupational or environmental exposure to inorganic dusts. Workers who inhale particles of silica are at risk for *silicosis*; similarly, workers in beryllium mines may develop *berylliosis*. Interstitial lung diseases may also be caused by inhaling organic dusts such as bacteria. Lung disease that results from breathing in animal proteins is called *hypersensitivity pneumonitis*. Drugs, poisons, infections, and radiation have also been known to cause these diseases. However, approximately two-thirds of the cases of interstitial lung diseases have no known cause and are therefore termed "idiopathic."

Interstitial lung diseases begin with inflammation of the lung cells. This may be caused by an immune response or injury. The lungs stiffen as a result of inflammation of the air sacs *(alveolitis*) and scarring (*fibrosis*).

Disorders of Gas Exchange and Blood Circulation

Pulmonary edema occurs when excess fluid collects in the tissues and air spaces of the lungs. The fluid interferes with gas exchange, thus causing the patient to be short of breath and to possibly have wheezing and a persistent cough. Pulmonary edema may result from diseases of the heart or may occur as complications of other illnesses such as widespread viral or other infections, drug toxicity, exposure to high altitudes, kidney failure, or hemorrhagic shock.

Pulmonary embolism is the sudden blocking of the blood flow in one of the arteries in the lung. The highly branched network of blood vessels in the lung filters the blood as it flows through it. Sometimes the blood carries a blood clot, a fat globule, an air bubble, or a piece of tissue that is large enough to block a blood vessel leading to the lung's network of capillaries. Gas exchange then can no longer occur in this section of the lung. The result is shortness of breath or even heart failure. The most common form of pulmonary embolism is a *thromboembolism*. It occurs when a blood clot travels from the legs or pelvis to the pulmonary blood vessels.

Respiratory failure is the inability of the lungs to perform gas exchange. It occurs either when the muscles of the ventilatory system fail or when the structures that perform gas exchange are unable to function. Patients with neuromuscular diseases such as muscular dystrophy and polio may have normal lungs, but they can develop respiratory failure because their disease-weakened muscles are unable to pump air into their lungs. When gas exchange is impaired, not enough oxygen gets into the blood to fuel the body's metabolic activity. This condition is called *hypoxemia*. Chronic hypoxemia causes the blood vessels in the

lung to contract; the result is *pulmonary hypertension*. Hypoxemia may also weaken the heart and the circulatory system. Any lung disease, if not adequately treated, can lead to respiratory failure.

Adult or acute respiratory distress syndrome (ARDS) was once called "shock lung." It is a type of pulmonary edema that is not related to heart problems. It has many causes such as severe infections, exposure to toxic fumes, circulatory collapse, sepsis (presence of disease-causing organisms or their toxic products in blood or other tissues), shock following severe blood loss, and bone fractures. During ARDS, there is severe damage to the alveolar surfaces, the blood-air barrier becomes leaky, and protein-containing fluid fills the alveoli so that they can no longer conduct gas exchange.

Respiratory distress syndrome of the newborn (RDS) is a type of respiratory failure that develops most commonly in premature or low birth weight babies whose lungs have not yet made enough surfactant. The surfactant is critical for opening the baby's alveoli with its first breath and keeping them open. As the lungs collapse, respiratory distress occurs.

Pulmonary hypertension is a disorder in which the blood pressure in the pulmonary arteries is abnormally high. In severe pulmonary hypertension, the right side of the heart must work harder than usual to pump blood against the high pressure. When this continues for long periods, the right heart enlarges and functions poorly, and fluid collects in the ankles (edema) and the belly. Eventually the left side of the heart begins to fail. Heart failure caused by pulmonary disease is called *cor pulmonale*. The most common causes of cor pulmonale are various combinations of emphysema, chronic bronchitis, and/or fibrosis. When pulmonary hypertension occurs in the absence of any other disease, it is called primary pulmonary hypertension. It affects more women than men; its cause is not known.

Pulmonary hypertension that results from another disease of the heart or lungs (for example, congenital heart disease, pulmonary thromboembolism, COPD, or interstitial fibrosis) is called secondary pulmonary hypertension.

Lung Disorders From Unusual Atmospheric Pressure

At high altitudes, the air pressure is less than at sea level, and the air contains less oxygen. Some individuals traveling to high altitudes experience a variety of symptoms while they adapt to changes in the atmosphere. The symptoms are probably due to excess fluid accumulation in the tissues.

- *Acute mountain sickness* causes dizziness, headache, and drowsiness; lethargy, shortness of breath, and nausea and vomiting may also occur.
- *High altitude cerebral edema* (fluid in brain tissue) is diagnosed when a person has symptoms of severe headache, confusion, nausea, and vomiting. Seizures may occur that can lead to coma and even death.
- *High altitude pulmonary edema* (fluid in the lung tissue) may cause cough and shortness of breath on exercise or, when severe, progressive shortness of breath even at rest, suffocation, and death.

When people dive into deep water below sea level, they become exposed to increased atmospheric pressures. This causes greater than normal amounts of nitrogen to become dissolved in their blood. If the diver returns too quickly to the surface, the excess nitrogen leaves the blood in the form of bubbles that lodge in the blood vessels of vital organs, causing necrosis (cell death) in surrounding tissue. Although this condition (*decompression sickness*) typically involves the limbs near a joint and is known as the bends, it can also occur in the chest, lung, or brain.

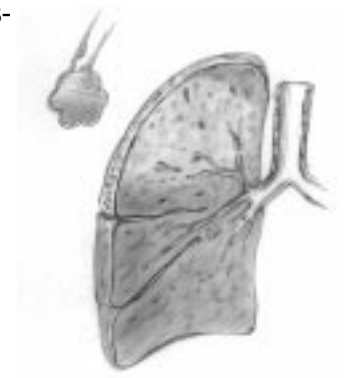
Disorders of the Pleura

Pleural effusion means an accumulation of fluid in the pleural space. It may result from heart failure, cancer, pulmonary embolism, or inflammation. If the pleurae themselves are inflamed, the condition is called *pleurisy*. Pleurisy causes severe chest pain with every breath and may occur with pleural effusion. If blood is the accumulating fluid, the condition is referred to as *hemothorax*. If the accumulating liquid is pus, it is called *empyema*.

When air accumulates in the pleural spaces, the condition is called *pneumothorax*. Mechanical injuries or diffuse diseases of the lung that distort lung architecture can lead to pneumothorax. Such diseases include emphysema, asthma, and cystic fibrosis. The most common symptom of pneumothorax is sudden pain on one side of the lung accompanied by shortness of breath.

Infections

Infections are a major cause of respiratory illness. They can be caused by bacteria or viruses and can affect not only the lung but also the nose, sinuses, ears, teeth, and gums. Infections may also complicate other lung diseases.



Lobar Pneumonia

Pneumonia, or inflammation of the lungs, is the most common type of infectious disease of the lung. Infectious pneumonias are usually identified by naming the cause of the infection or the pattern of the infection in the respiratory tract. More than half

the cases of pneumonia are caused by the bacterium, *Streptococcal pneumoniae (pneumococcus)* and are called pneumococcal pneumonia. *Influenza A* is the cause of a significant number of cases of pneumonia in the elderly during the winter months. Another well-known form of pneumonia is *Legionnaires' disease*, which is caused by the organism, *Legionella pneumophila*.

The inflammatory response of the lung in pneumonia varies depending on the type of infection, and might include:

- lobar consolidation: solidification of the lung as air spaces are filled with fluid and cellular material, and
- interstitial inflammation.

Pneumonia is sometimes accompanied by:

- necrosis: tissue changes accompanying cell death,
- cavitation: hollow spaces walled off by scar tissue,
- abscess: pus formation, and
- granuloma formation: production of tumor-like masses of different kinds of cells due to a chronic inflammatory response.

Tuberculosis is a granulomatous infectious disease caused by an organism called *Mycobacterium tuberculosis*.

Abscess (Bacterial or Tubercular)

Lung Cancer

More than ninety percent of lung cancer patients are or have been cigarette smokers.

Deaths from lung cancer were virtually unknown in the United States until 1900, but have steadily increased since then. Currently, lung cancer is responsible for almost one-third of all cancer deaths in this country. The incidence of lung cancer may have reached its peak in men, but it is continuing to rise in women. More than 90 percent of patients with lung cancer are, or have been, cigarette smokers. Smoking marijuana increases the risk of cancer for cigarette smokers. Quitting cigarette smoking reduces the incidence of lung cancer, but the level of risk reaches that of a nonsmoker only after the person has remained a nonsmoker for 10 to 15 years.

Types of Lung Cancer: Cancers of the cells that line the major bronchi or their primary branches are called *squamous cell carcinomas*. This type of cancer metastasizes (spreads) mostly to other sites within the thorax. *Adenocarcinomas* are cancers of the glandular cells that line the respiratory tract. They most often start at the outer edges of the lungs and spread to the brain, the other lung, liver, and bones. *Large cell carcinomas* usually begin in the outermost parts of the lung. By the time they are diagnosed, they are often seen as large, bulky tumors. *Small cell carcinomas*, also called "oat cell" cancers, usually begin in the bronchi. Small cell carcinomas metastasize widely to the mediastinum, liver, bones, bone marrow, central nervous system, and pancreas.

Cancer

Diagnosing Lung Diseases

When a person's symptoms suggest lung disease, a chest x ray is usually the first examination the doctor orders. Then various tests are performed to identify the disease and to determine how severe it is. These tests include:

- pulmonary function tests;
- microscopic examination of lung tissue, cells, and fluids using a light microscope and an electron microscope; and
- biochemical and cellular studies of respiratory fluids removed from the lung by lavage (washing).

To determine how well the lungs are working, doctors can measure respiratory or gas exchange functions, airway or bronchial activity, particle clearance rates, and permeability of the blood-air barrier.

Spirometry

Spirometry, like the measurement of blood pressure, is useful for assessing lung function as well as general health. It is the simplest and most common of the lung function tests.

Spirometry measures how much and how quickly air can be expelled following a deep breath. It is performed by having the patient breathe out forcefully into a device called a spirometer. At the same time a machine makes a tracing of the rate at which the air leaves the lung. Diseases of airflow obstruction and of lung stiffening give characteristic tracings with spirometry.

Measures of the amount of air that can be expelled following a deep breath, forced vital capacity (FVC), and the amount of air that can be forcibly exhaled in 1 second, forced expiratory volume in 1 second (FEV_1), are the most useful numbers derived

from spirometry. The ratio of FEV_1 to FVC is often used to assess patients for airflow obstruction. It is normally 75 to 85 percent, depending on the patient's age. The ratio is reduced in obstructive diseases, while it is preserved or even increased in restrictive disorders. A lower than normal FEV_1 is a sign that a lung disease is present. A falling FEV_1 is a sign that a person's lung disease is getting worse.

The "normal" values for FVC and FEV_1 for a patient depend on the individual's age, gender, height, and race. They are higher for younger than for older people, higher for tall than for short individuals, higher for men than for women, and higher for whites than blacks or Asians. Therefore, the numbers are presented as percentages of the average expected in someone of the same age, height, sex, and race. This is called percent predicted. Any number smaller than 85 percent of predicted is considered abnormal.

Smokers should have spirometry done at least every 3 to 5 years.

If these numbers are abnormal, the patient is referred for additional pulmonary function tests to find out why. These may include checking the patient's response to bronchodilators, absolute lung volumes, and blood levels of oxygen and carbon dioxide which tell how well gas exchange is occurring. Other important measures of lung function are arterial blood gas tensions (PaO_2 and $PaCO_2$) and the diffusing capacity of the lung for carbon monoxide (DLCO).

Some doctors recommend having spirometry before age 25 to get baseline numbers. However, if you are a smoker, are occupationally exposed to irritants, or have symptoms of cough, wheeze, or shortness of breath, you should be checked with a spirometer at intervals of 3 to 5 years or more frequently if your doctor recommends it.

Abnormal spirometry numbers at any age means that you are at risk for early lung disease and even potentially fatal lung cancer, heart disease, or stroke. You should immediately stop smoking if you still smoke, and talk to your doctor about other measures you may need to take depending on the reasons for your abnormal numbers.

Preventing Lung Diseases

Because respiratory problems are so often caused by environmental exposure to irritants and infectious agents, smoking tobacco, and occupations that involve inhaling dangerous substances, many lung diseases can be prevented by following some simple guidelines:

- Do not smoke tobacco or other products.
- Avoid exposure to dusts and irritants that can harm your lungs.
- Wear proper protective devices if you must work in environments that contain respiratory irritants.
- Have spirometry done as often as recommended by your doctor to get to know your numbers.

More on Lung Structure and Function: Cellular and Molecular Aspects

At the cellular and molecular level, the components of the lung are maintained by a unique arrangement of diverse structural proteins and cellular elements. This includes some 40 different types of cells, glands, muscles, and molecules, strategically arranged in intricate but orderly patterns in various parts of the lung. The controlled complexity of the various parts of the lungs facilitates their many functions.

Oxygen-poor blood is pumped from the right ventricle of the heart through a system of pulmonary arteries, arterioles, and capillaries to the alveoli, and the oxygen-rich blood is returned to the left heart through a collecting system of venules and veins. This extensive system, called the pulmonary circulation, filters clots, fat particles, and cellular debris from the bloodstream. It also moves liquid and large and small molecules across the pulmonary blood vessels, providing oxygen and nutrients, and facilitating various metabolic functions of the lung including the synthesis of substances such as surfactant.

The lungs also have a second blood supply from the bronchial circulation. The purpose of this blood supply is to provide nutrients especially for the large airways. Bronchial circulation represents only a small portion (1-2 percent) of the cardiac output. In this system, bronchial arteries bring oxygenated blood from the left side of the heart to the airways (bronchi, bronchioles) and the supporting structures (connective tissue) of the lung. Bronchial venous blood is returned, just like the venous blood from the rest of the body, to the right atrium.

Bronchial circulation is believed to be more important in the fetal lung than in the adult lung. Conducting airways receive their blood supply from branches of bronchial arteries, while the terminal respiratory units receive blood from branches of the pulmonary arteries.

Gas exchange occurs by diffusion of gases across the alveolar membranes into and out of the blood as it flows through the capillaries. Oxygen-poor blood discards its carbon dioxide into the alveoli, and hemoglobin, an oxygen-carrying protein in the red blood cells, binds with oxygen from inhaled air (becomes "arterialized"). Although the red blood cells are exposed to alveolar air only for a fraction of a second, gas exchange between alveoli and capillaries takes place very efficiently because there is an extremely large surface area between the blood and the air.

The bronchi contain specialized connective tissue (cartilage), while bronchioles are noncartilaginous. The bronchi mostly serve nonrespiratory roles such as ridding the airways of irritating particles; their only respiratory function is to carry air from the external environment to the distal sites of gas exchange.

The arteries and capillaries that bring blood to the alveoli are lined with a layer of delicate specialized cells called endothelial cells. The air-blood barrier is composed of three tissue layers—an endothelium lining the capillaries; an epithelium lining the airspaces; and, between them, an interstitial layer composed of connective tissue, interstitial extracellular matrix, and mesenchymal cells. The interstitial layer also contains special cells—alveolar macrophages, lymphocytes, and inflammatory cells—that can defend or injure the lungs, depending on the situation. Dispersed throughout the interstitium are proteins, lipids, carbohydrates, and other substances derived from plasma and cells.

The endothelium acts as a barrier retarding the passage of fluid, proteins, and other blood components from the vessel lumen into the interstitium and air spaces of the lung. In addition, the endothelial cells perform many of the nonrespiratory functions of the lung, particularly the transformation of a variety of bioactive substances.

The walls of the conducting airways are mostly composed of epithelial lining, connective tissue elements, and a smooth muscle sleeve. The exact proportion of these constituents varies depending on whether the walls are in the large bronchi, the bronchioles, or the alveoli. The epithelium also contains unique mixtures of cells with distinct functions. These functions vary depending on the level of the airway at which the cells are located.

The lungs' first line of defense against injury from inhaled agents is a mix of anatomic barriers, nonspecific mechanical and cellular defenses, antimicrobial secretions, and circulating and resident scavenger (phagocytic) cells that engulf or digest particulates. Removal of particles from the conducting airways (nose to respiratory bronchioles) is carried out by "mucociliary clearance," helped by airway secretions. A film of mucus produced in the lungs envelops the particles which are then continuously moved by the rhythmic beating motions of cilia (hair-like structures that extend from the surface of the cells) to the oropharynx where they are swallowed or coughed out. These defenses are present at birth.

Operating beyond the nonspecific defenses, are specific acquired immune mechanisms that are latent until activated by natural (maternal transfer or infections) or artificial exposures (vaccinations) to foreign materials. These highly specific defenses of the lung are initiated by complex interactions between foreign substances (antigens) and specialized cells. These interactions result in antibody-mediated or cell-mediated immunities that provide uniquely specific defenses against certain organisms or agents.

Research supported by the National Heart, Lung, and Blood Institute is generating new knowledge on previously unrecognized physiological and metabolic processes and mediators operating in the lung. Scientists now realize that the lung, an organ once thought to be merely an inert balloon serving as a receptacle for air, is in reality a powerhouse of concerted and interrelated mechanical, physiological, neurological, immunological, pharmacological, and metabolic functions necessary to sustain life.

FOR MORE INFORMATION

The NHLBI Information Center is a service of the National Heart, Lung, and Blood Institute (NHLBI) of the National Institutes of Health. The Information Center provides information to health professionals, patients, and the public about the treatment, diagnosis, and prevention of heart, lung, and blood diseases.

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In addition, the National Heart, Lung, and Blood Institute maintains a World Wide Web (WWW) site at:

http://www.nhlbi.nih.gov/nhlbi/nhlbi.htm

GLOSSARY

Acute: Severe or with sudden onset and a short timespan.

Acute respiratory failure: Sudden, severe inability to perform gas exchange.

Airways: Tubes that carry air into and out of the lungs.

Airway obstruction: Narrowing, clogging, or blocking of the air passages.

Alveoli: Tiny sac-like air spaces in the lung where carbon dioxide and oxygen are exchanged.

Amniotic fluid: Fluid that surrounds and cushions the fetus in its mother's womb.

Antibodies: Specific proteins produced by the body's immune system that bind with foreign proteins (antigens).

Antigens: Substances that activate the immune system and react with antibodies produced by the immune response.

Aorta: Largest artery in the body; delivers oxygen-rich blood from the heart to the body.

Arterioles: Smallest arteries in the body.

Artery: Blood vessels that carry blood away from the heart. All arteries carry oxygen-rich blood except the pulmonary artery and its branches through which oxygen-poor blood is pumped from the heart to the lungs.

Asthma: Respiratory condition marked by recurrent attacks of wheezing, coughing, shortness of breath, and labored breathing caused by narrowing of the airways.

Atrium: One of the two upper chambers of the heart. The right atrium receives blood depleted of oxygen from the veins; the left atrium receives blood with fresh oxygen from the lungs.

Blood Pressure: Pressure of the blood against the walls of the blood vessels.

Bronchi: Larger air passages of the lungs.

Bronchiectasis: Chronic dilation of the bronchi and bronchioles.

Bronchioles: Smaller air passages of the lungs.

Bronchiolitis: Inflammation of the smallest bronchioles, usually caused by viral infections.

Bronchitis: Inflammation of the bronchi. Acute bronchitis comes on suddenly and usually clears up in a few days. Chronic bronchitis lasts for a long period and recurs over several years.

Bronchoconstriction: Tightening of the muscles surrounding the bronchi; opposite of bronchodilation.

Cancer: A term for more than 100 diseases in which abnormal cells multiply without control.

Capillaries: The tiniest blood vessels. Capillary networks connect the arterioles and venules.

Carbon dioxide: Waste gas resulting from chemical reactions in the body cells.

Carcinoma: Cancer of the epithelial tissue lining or covering an organ.

Cartilage: Flexible, rubbery connective tissue that cushions bones and joints.

Cell: Basic subunit of every living organism; the simplest unit that can exist as an independent living system.

Chronic: Of long duration; frequently recurring.

Chronic obstructive pulmonary disease (COPD): Lung disease in which both chronic bronchitis and emphysema are present.

Connective tissue: Tissue that connects, supports, or surrounds other tissues and organs.

Cor pulmonale: Heart disease due to resistance to the passage of blood through the lungs; it often leads to right heart failure.

Cough: Natural body mechanism for ridding the respiratory tract of irritating and harmful substances.

Cystic Fibrosis: A serious genetic disease of excretory glands affecting the lungs and other organs. It causes production of very thick mucus that interferes with normal digestion and breathing.

Diaphragm: The muscle that separates the chest from the abdomen.

Duct: A passage or tube with well-defined walls for the passage of air or liquids.

Dyspnea: Shortness of breath; difficult or labored breathing.

Edema: Abnormal accumulation of fluid in body tissues.

Embolism: Sudden blocking of an artery by a clot or a bit of foreign material brought to the site by the bloodstream; usually a blood clot but may be a fat globule, air bubble, piece of tissue, or a clump of bacteria.

Emphysema: Chronic lung disease in which there is permanent destruction of the alveoli.

Endothelium: Layer of epithelial cells lining the circulatory system.

Epithelium: Layer of tissue that covers surfaces of organs.

Esophagus: The tube through which food passes from the throat to the stomach.

Expiration: Act of breathing out (exhalation).

Fibrosis: Formation of fibrous tissue as inflamed tissue becomes scarred.

Gas exchange: Primary function of the lungs involving transfer of oxygen from inhaled air into blood and of carbon dioxide from blood into the lungs for exhalation.

Genetic disease: Disease caused by defective genes (basic unit of heredity) inherited from one or both parents.

Granulomas: Small lumps of cells caused by some types of chronic inflammation.

Hemoglobin: The iron-containing protein in red blood cells that carry oxygen to the tissues.

Hemorrhage: General term for loss of blood caused by injury to the blood vessels or by a low level of the blood elements necessary for clotting.

Hemothorax: Accumulation of blood in the cavity around the lungs.

Hilum: The area where bronchi, blood vessels, and nerves connect to each lung.

Hypersensitivity pneumonitis: A group of allergic lung disorders that result from inhaling substances such as dusts and molds.

Hypertension: High blood pressure.

Hypoxemia: Not enough oxygen in the blood.

Immune system: Complex group of organs and cells that defend the body against infections and disease.

Infection: Invasion and multiplication of disease-producing organisms in the body.

Inflammation: Response of body tissues to injury. Typical signs are heat, swelling, redness, and pain.

Inspiration: Taking air into the lungs (inhalation).

Lavage: To wash out a body organ or cavity.

Lung volume: Amount of gas in the lungs. The total volume of gas in the lungs is subdivided into compartments (volumes) and capacities (combinations of two or more volumes). Tidal volume (TV or VT) is the volume of air that enters the lungs during inspiration and leaves during expiration. Functional residual capacity (FRC) is the volume of air remaining in the lungs at the end of normal exhalation. Total lung capacity (TLC) is the volume of air in the lungs following a maximal inspiration. Vital capacity (VC) is the maximal volume of air that can be expelled from the lungs following maximal inspiration. Residual volume (RV) is the volume of air remaining in the lungs after maximum expiration. In general, lung volumes increase in obstructive lung diseases and decrease in restrictive lung diseases.

Lobe: A well-defined, demarcated portion of an organ or gland.

Lymph nodes: Small, bean-shaped organs located along the lymphatic vessels that filter bacteria, toxins, or cancer cells; also called lymph glands.

Membrane: Thin, flexible film of proteins and lipids that encloses a cell's contents, controlling what goes in and what comes out of the cell; also a thin layer of tissue that covers a surface or lines a cavity that also controls the substances that enter and leave an organ.

Mesenchymal: Pertaining to the connective tissue that connects and supports the various structures in the body.

Metabolic processes: Chemical processes by which food and oxygen are transformed into other chemicals in the body.

Metastasize: To form new sites of cancer in different organs or tissues not directly connected with the original cancerous tumor.

Molecule: Smallest possible physical amount of a substance.

Mucus: Thin, slippery fluid secreted by mucous membranes and glands; becomes thick and sticky in lung disease.

Nutrients: Substances that are necessary for growth, development, and maintenance of life; food.

Obstructive lung diseases: Disease due to narrowing of any portion of the airways that obstructs airflow; examples are COPD, cystic fibrosis, and asthma.

Oxygen: Colorless, odorless gas that makes up about 20 percent of the air we breathe. It is essential to life because it is used for the chemical reactions that occur in the cells of the body.

PaO_2: Oxygen tension of arterial blood.

$PaCO_2$: Carbon dioxide tension of arterial blood.

Pathophysiology: Altered functions in an individual or an organ due to disease.

Pleura: Membrane that surrounds the lungs and lines the thoracic cavity.

Pneumonia: Inflammation of the lungs.

Pneumonitis: Inflammation of the lung tissue.

Pneumothorax: Accumulation of air or gas in the pleural cavity resulting in partial or complete collapse of the lung.

Proteins: Naturally occurring organic compounds essential to the structure and function of the body.

Pulmonary: Relating to the lungs.

Pulmonary artery: Blood vessel that delivers oxygen-poor blood from the right ventricle of the heart to the lungs.

Pulmonary embolism: Closure or narrowing of the pulmonary artery or one of its branches by an embolism.

Pulmonary function tests: Procedures used for measuring how well the lungs are working. The most common tests measure the ability of lungs to move air into and out of the lung.

Pulmonary hypertension: Abnormally high blood pressure in the arteries of the lungs.

Red blood cells: Cells that transport oxygen from the lungs to all tissues of the body.

Respiration: Process of exchanging oxygen from the air for carbon dioxide from the body; includes the mechanical process of breathing, gas exchange, and oxygen and carbon dioxide transport to and from the cells.

Respiratory failure: Inability of the lungs to conduct gas exchange.

Respiratory tree: The structure in the chest composed of the trachea, bronchi, bronchioles, and alveoli. It resembles an upside-down tree; also called the tracheobronchial tree.

Restrictive lung diseases: Diseases that interfere with lung inflation; examples are pulmonary fibrosis, sarcoidosis, pneumoconioses, diseases of the chest wall and pleura, and those of neuromuscular origin.

Sarcoidosis: Rare disease of unknown cause, occurring primarily in young adults, that can affect the function of the lungs as well as other organs and tissues.

Silicosis: Lung disease caused by inhaling dust containing silica.

Smooth muscle: Muscle that involuntarily performs automatic tasks such as constricting blood vessels.

Spirometer: Instrument used to measure lung air volumes and flow rates.

Squamous cell carcinoma: Cancer that begins in the flat scale-like cells in the skin and in tissues that line certain organs of the body including the larynx.

Surfactant: Fluid secreted by alveolar cells that reduces the surface tension of pulmonary fluids and contributes to the elastic properties of pulmonary tissue.

Surface tension: Property of a liquid, related to its chemical structure, that causes its exposed surface to contract to the smallest area.

Thoracic cage: Bony structure formed by 12 pairs of ribs, the sternum (breastbone) and vertebrae (back bone).

Thorax: The body between the neck and the abdomen; the chest.

Tissue: A group or layer of similar specialized cells that perform specific functions.

Trachea: Airway that connects the larynx to the lungs; also called the windpipe.

Vein: Blood vessel that carries blood to the heart. All veins carry oxygen-poor blood except the pulmonary vein and its branches which carry oxygen-rich blood to the heart. The smallest veins are called venules.

Venous blood: Blood that has given up its oxygen to the tissues in exchange for carbon dioxide which it carries back to the lungs for gas exchange.

Ventilation: Exchange of air between the lungs and the atmosphere so that oxygen can be exchanged for carbon dioxide at the alveoli.

Ventricle: A chamber of the heart that pumps blood out. The right ventricle pumps it to the lungs where it picks up oxygen; the left ventricle pumps it into the aorta and then on to the rest of the body.

Virus: Infectious agent composed of a protein coat around a nucleic acid core; viruses depend on living cells to reproduce.

Wheezing: Breathing with a rasp or whistling sound; a sign of airway constriction or obstruction.

Discrimination Prohibited: Under provisions of applicable public laws enacted by Congress since 1964, no person in the United States shall, on the grounds of race, color, national origin, handicap, or age, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity (or, on the basis of sex, with respect to any education program or activity) receiving Federal financial assistance. In addition, Executive Order 11141 prohibits discrimination on the basis of age by contractors and subcontractors in the performance of Federal contracts, and Executive Order 11246 states that no federally funded contractor may discriminate against any employee or applicant for employment because of race, color, religion, sex, or national origin. Therefore, the National Heart, Lung, and Blood Institute must be operated in compliance with these laws and Executive Orders.

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